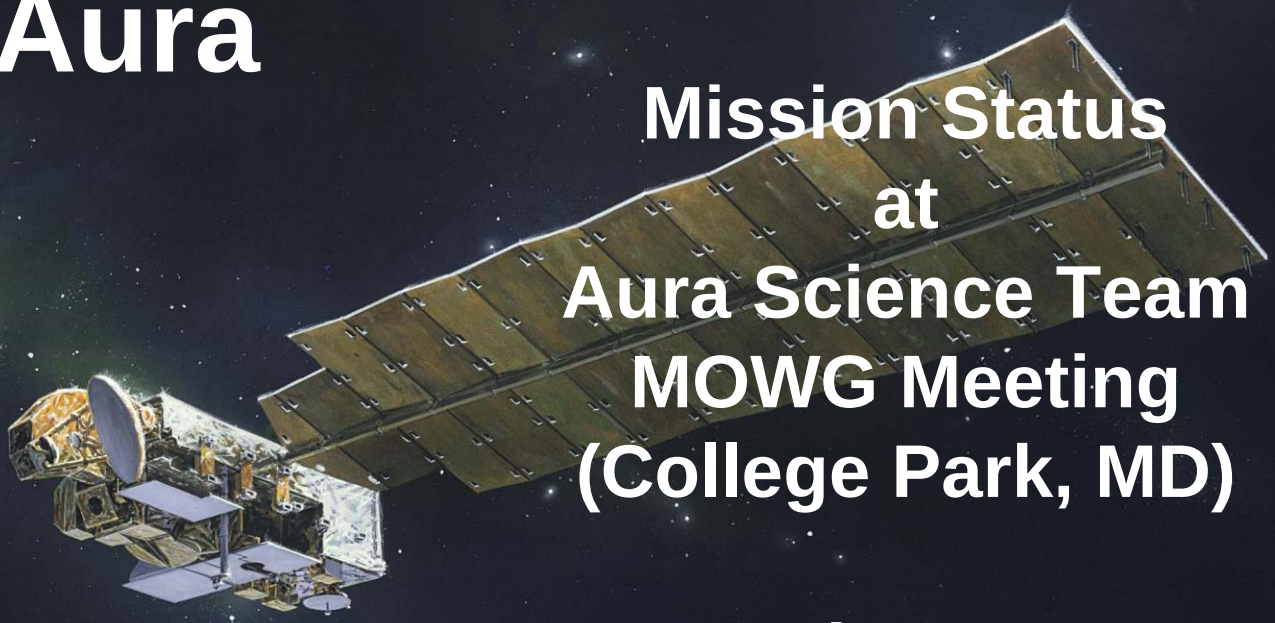
EOS Aura



Mission Status
at
Aura Science Team
MOWG Meeting
(College Park, MD)

September 16, 2014

Bill Guit

Aqua/Aura Mission Director - Code 584

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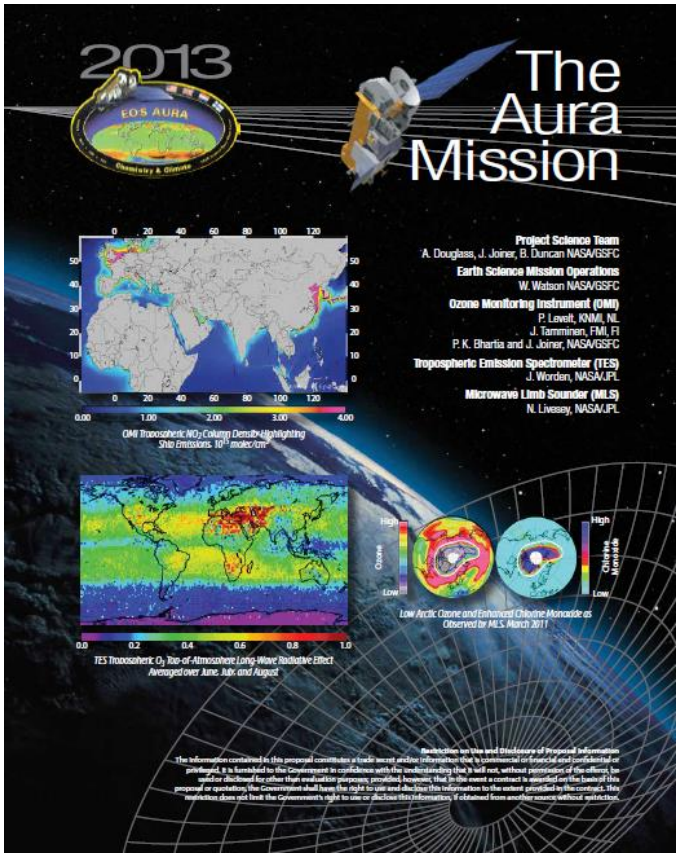
Topics

- **Mission Summary**
- **Spacecraft Subsystems Summary**
- **Recent & Planned Activities**
- **Spacecraft Anomalies**
- **Data Capture**
- **Propellant Usage** & Lifetime Estimates
- **Overall Summary**
- Additional Slides:
  - Spacecraft Maneuvers & Ground Track History
  - Mission Highlights & Past Spacecraft Anomalies
  - Reliability Estimates

EOS Aura Mission Summary

(Changes since October 2012 MOWG @ JPL)

- 07/15/04: Launch
  - 6-Year Design Life
- 09/30/10: End of Prime Mission Review
- 10/01/12: STM & MOWG @ JPL
- 03/01/13: Senior Review Proposal #3
  - Reliability Estimates thru 2021
  - Consumables through 2023+
- 07/10/13: 2013 Mission Extension Senior Review Proposal Panel Report
  - #4 Ranked Earth Science Mission
  - Mission extension through FY17
- 07/15/13: Aura 9-Year Anniversary
- 07/22/13: Submitted Phase F Study
- 07/15/14: 10-Year Anniversary



Aura Spacecraft Subsystems

(Changes since October 2012 MOWG @ JPL)

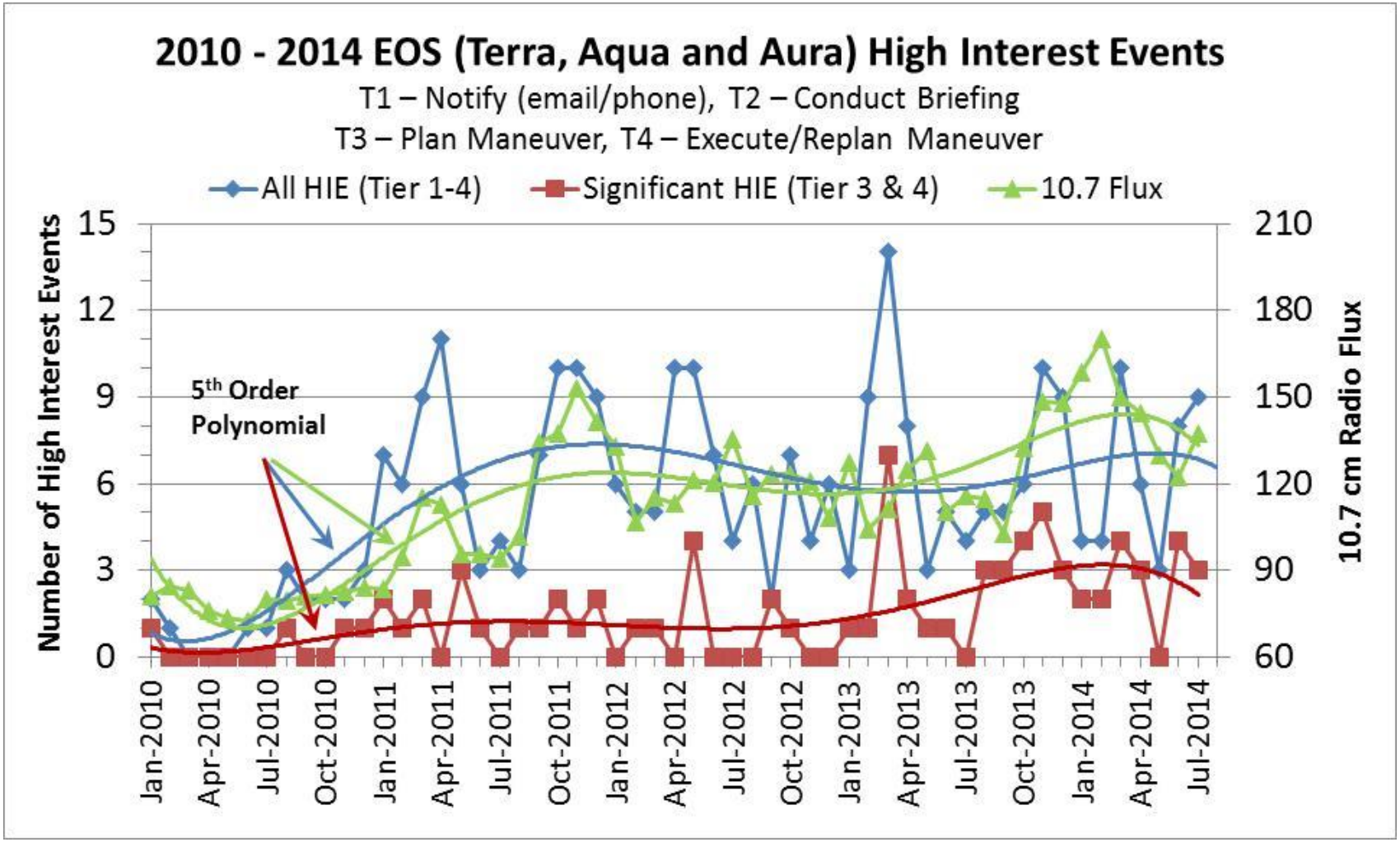
- **Command & Data Handling (CDH) – Nominal**
  - ***Solid State Recorder (SSR) Anomaly (December 4-18, 2007)***
    - » ***Returned November 2010 at reduced level – then subsided January 2011***
    - » ***Returned again 04/15/2012 – currently still "active"***
- **Communications (COMM) – Nominal**
- **Electrical Power System (EPS) – Nominal**
  - ***Solar Panel Connector Anomaly – ARE-3C (January 12, 2005)***
  - ***Solar Array Offset (Reported 11/17/09, Corrected 06/29/10 and each year since)***
  - ***Array Regulator Electronics (ARE) 5A Anomaly (03/12/2010)***
    - » ***Simultaneously with GN&C Attitude Disturbance – attributed to MMOD Strike***
    - » ***04/25/2013 additional ARE-5A power drop anomaly***
  - ***Other older ARE Anomalies: ARE-5C (9/27/12 & 2/4/13), ARE-1A (3/12/10 & 11/5/11) & ARE-6A (9/14/13)***
    - » ***Estimated that Aura has lost 22 strings of solar cells out of a total of 132 strings***
    - » ***Aura continues to have significant power margin where the life limiting item is fuel***
- **Flight Software (FSW) – Nominal**
- **Guidance, Navigation & Control (GN&C) – Nominal**
  - ***Earth Sensor Assembly (ESA) Anomaly (05/29/2009) – Re-calibrated in Fall 2009***
- **Propulsion (PROP) – Nominal**
  - ***Dual Thruster Module (DTM-3) Anomaly (Aug 16, 2005)***
- **Thermal Control System (TCS) – Nominal**

All subsystems configured to primary hardware

Summary of Activities
(Since the last MOWG on 10/01/2012)

- **51 CARA High Interest Orbital Debris Events (Tiers 1-4)**
  - **22+ that required significant action (see backup charts 29-31)**
    - » 09/03/2013: First High Interest Event (HIE) with operational Chinese satellite (SJ-11-02)
    - » 11/15/2013: Moved up a planned DMUM from 11/20 to 11/15 (DAM#5)
    - » 06/15/2014: Modified planned DMUM to mitigate predicted close approach (DAM #6)
    - » 08/29/2014: Advanced a planned DMUM to mitigate multiple conjunctions on 9/2 (DAM #7)
    - » **15+** Risk Mitigation Maneuvers (RMMs) were planned but the risk-level rolled off
    - » **4** DMUMs re-scheduled due to post-maneuver conjunctions of concern (PMCs)
- **3 Spacecraft EPS ARE power drop anomalies – no impact to operations**
  - **2/4/2013 (ARE-5C), 4/25/2013 (ARE-5A) & 9/14/2013 (ARE-6A)**
- **8 Significant instrument related anomalies (Generated NASA Anomaly Reports)**
  - **TES: 3 Safe Events (9/21/13, 11/24/13 &12/4/13), 1 Stall (5/18/14) & Laser-A Failure (7/9/14)**
  - **MLS: 3 Signal Chain Related (10/17/12, 9/16/13 & 8/19/14)**
- **Spacecraft Delta-V Maneuvers: 24 Routine DMUMs and 8 IAMs**
- **2 Instrument Calibration Maneuvers**
  - **03/29/2013: MLS Yaw Slew #8 Lunar Calibration**
  - **03/18/2014: MLS Yaw Slew #9 Lunar Calibration**
- **Completed 2 Series of Annual Inclination Adjust Maneuvers (2013 & 2014)**
- **Completed 2 EOS Flight Operations Annual Reviews (1/30/13 & 2/20/14)**

EOS Debris Avoidance Activities



Planned Activities

- **09/24/2014: Drag Make Up Maneuver (DMUM) # 71**
- **10/16/2014: Drag Make Up Maneuver (DMUM) # 72**
- **January 2015: Flight Operations Annual Review (#8)**
- **March 2015: Submit Senior Review Mission Extension Proposal**
- **Spring 2015: Annual Inclination Adjust Maneuvers (DRAFT SCHEDULE)**
  - **3/19/15 (#41), 3/26/15 (#42), 4/2/15 (#43), 4/16/15 (#44) & 4/23/15 (#45)**

- **Mid-to-Long-Term Plans**
  - **Continuing performing "No Yaw Slew" maneuvers (DMU & RMM/DAM)**
  - **Continue to improve RMM/DAM responsiveness**
    - » See additional details on following slides
  - **Fall Earth Science Constellation MOWG (October 2014)**
    - » Update propellant budget, decommissioning analysis, reliability predictions,…
  - **2015 Senior Review Proposals**

New RMM/DAM Operations Concept

The EOS FOT/FDT is developing new operational procedures and products, to safely plan and execute Risk Mitigation Maneuvers (RMMs) and/or Debris Avoidance Maneuvers (DAMs) in a significantly reduced amount of time (hours vs. days)

This new and improved procedures and products will….

- **Eliminate the current critical path for instrument and communications subsystem commanding in the daily stored command load**
- **Require less personnel and man-hours for preparation**
- **Require fewer systems for preparation**
- **Require generation of fewer products**
- **Allow greater flexibility with burn duration & timing**

DRAFT Spring 2015 Inclination Adjust Plan

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1 March	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18 **Aqua IAM #43**	19 **Aura IAM #41**	20 Equinox	21
22	23	24	25 **Aqua IAM #44**	26 **Aura IAM #42**	27	28
29	30	31	1 April **Aqua IAM #45**	2 **Aura IAM #43**	3	4
5 Easter	6	7	8 **Spring Break**	9 **Spring Break**	10	11
12	13	14	15 **Aqua IAM #46**	16 **Aura IAM #44**	17	18
19	20	21	22 **Aqua IAM #47**	23 **Aura IAM #45**	24	25
26	27	28	29 **Aqua Backup**	30 **Aura Backup**		

Spacecraft Anomalies

Array Regulator Electronics Anomalies

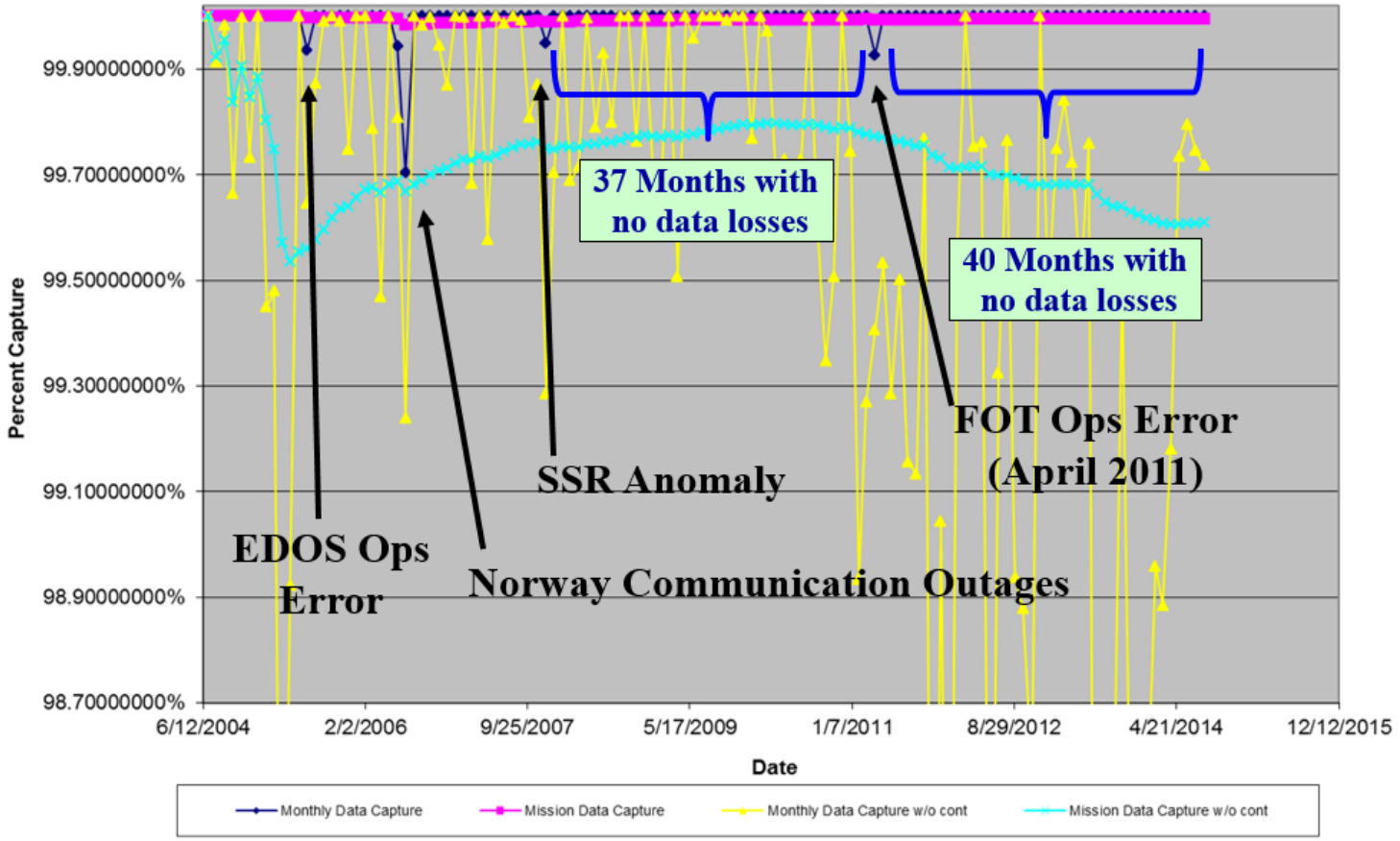
Current Status

No new Aura ARE Anomalies – Last ARE-6A on 09/14/2013

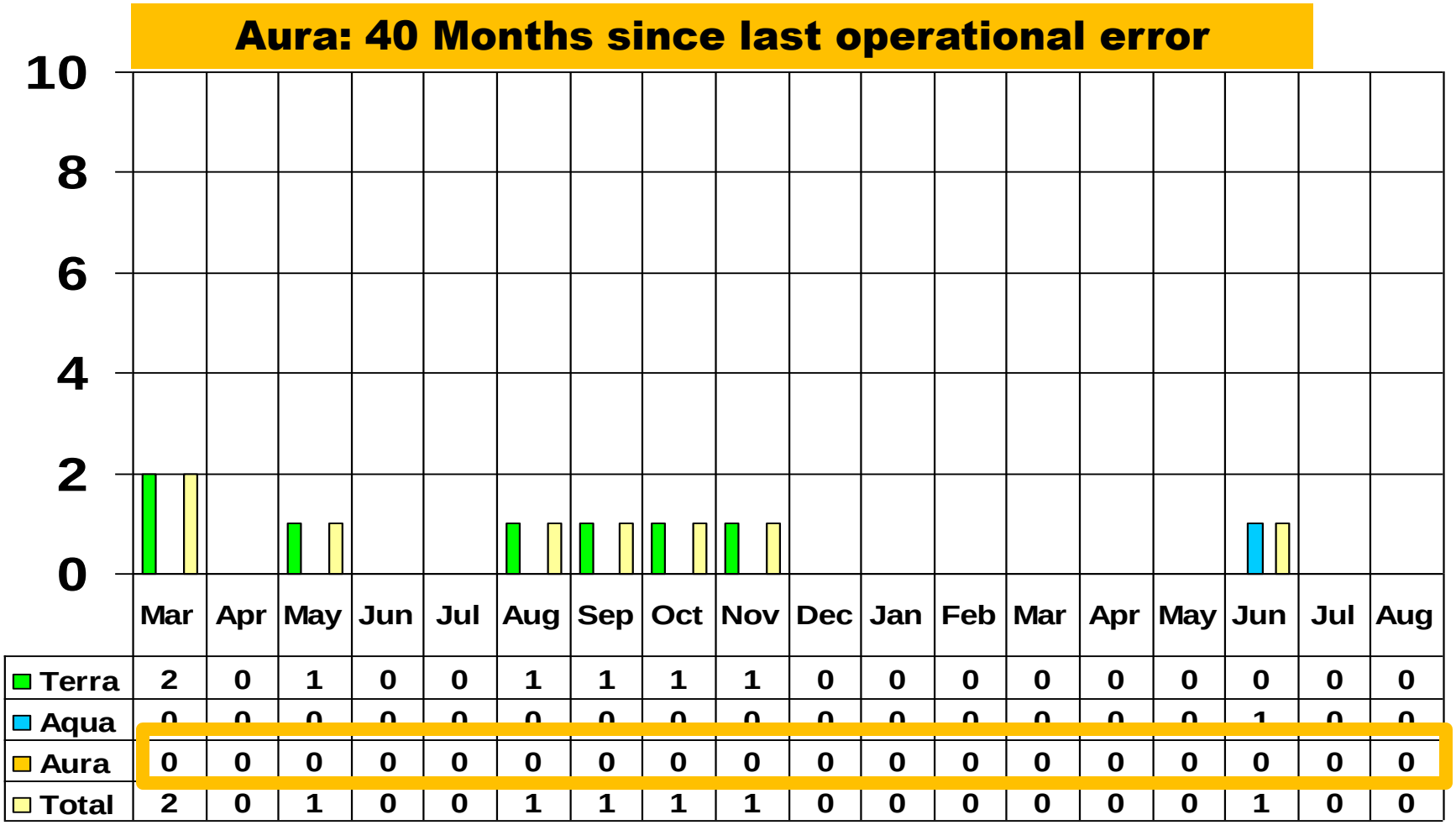
- **07/17/2013: Met with NGAS to review the results of their anomaly investigation to date (focus to date had been on Aqua ARE-6A that occurred 10/20/2011)**
  - **Loss could be for many possible reasons including short or open circuits**
  - **Most failure modes exhibited by Aqua and Aura appear most likely to be caused by loss of output from multiple solar array strings (see NGAS Fishbone Diagram Analysis & Final Report)**
  - **Additional Aura ARE Anomalies due to other causes**
    - » 01/12/2005: Disengaged Solar Array Connector (ARE-3C)
    - » 03/12/2010: MMOD (?) Vacuum Arching (ARE-5A)
- **09/25/2013: NGAS Follow-up Meeting (Focus on Aura investigation)**
- **09/27/2013: FOT reports ARE-6C current drop on 9/14 masked by TES transition to Safe on 9/22**
- **11/13/2013: NGAS Follow-up Meeting (Focus on Aura investigation)**
- **12/11/2013: NGAS Follow-up Meeting (Focus on Aura investigation)**
- **01/15/2014: EPS Performance Review & Anomaly Closeout → 02/05/2014 → 03/05/2014**
- **03/05/2014: NGAS Investigation Status Meeting**
- **03/21/2014: Follow-up/Close-out Meeting while NGAS was at GSFC**
  - **Aura appears to have lost output from about 22 of 132 strings – No impact to mission operations at this time**
  - **FOT & NGAS continues to closely monitor the overall performance of the Electrical Power System (EPS)**
  - **NGAS working on final anomaly report – expect delivery in mid-July**
- **06/04/2014: NGAS Briefing – Final Briefing/Report planned for July**
- **07/28/2014: NGAS delivers draft final report and presentation – ESMO currently reviewing**
- **09/17/2014: NGAS Briefing to ESMO and AETD at GSFC**

Data Capture – SSR Data Losses
October 2012 to August 2014

- 40 months without a solid state recorder (SSR) data loss
- Last loss April 2011: OMI data loss 107/21:08:49-22:13:04 (FOT Ops Error)
- SSR Data Capture to 8/31/2014: 99.99490238 %*



Operational Errors
(18-Months: March 2013 – August 2014)

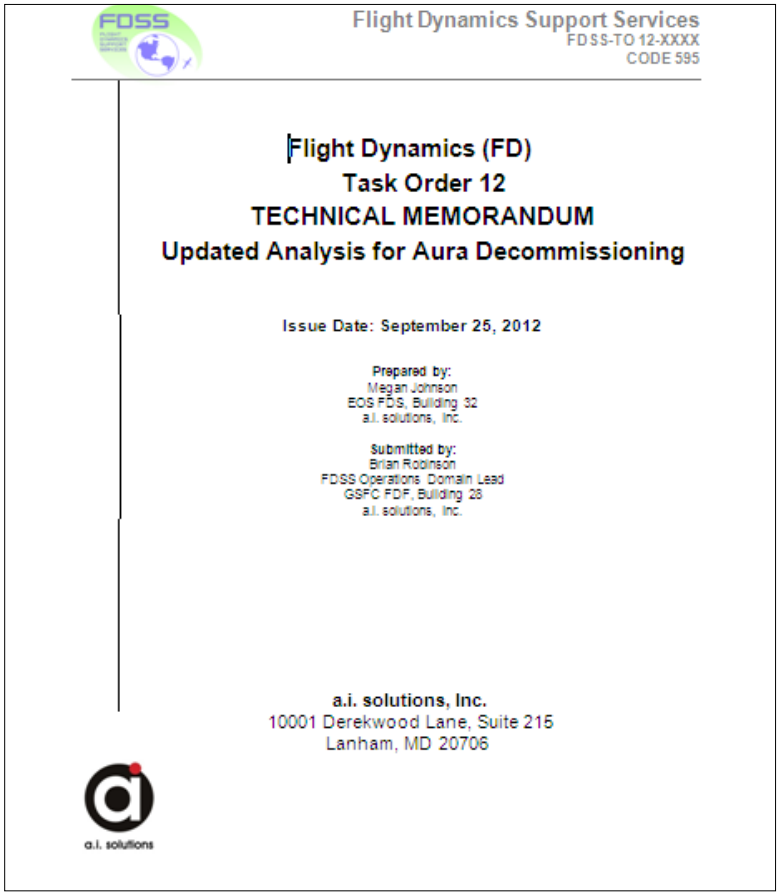


	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Terra	2	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
Aqua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Aura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2	0	1	0	0	1	1	1	1	0	0	0	0	0	0	1	0	0

Propellant Usage

(To be updated September 2014)

- **Initial Aura lifetime fuel analysis in 2006**
- **Detailed Aqua & Aura lifetime analysis in 2008**
  - **Presented to MOWG and at Aura End of Prime Mission Review in September 2010**
- **Annually updated end-of-life estimates**
- **Initial Aura Decommissioning Plan was delivered in September 2012**
  - **Updated Lifetime Estimates**
- **Updated August 29, 2013**
  - **Updated propellant trends for IAMs & DMUMs**
  - **Updated definitive fuel usage**
  - **Updated predicted solar flux levels**
  - **Updated Constellation Exit Plan**
    - Safely exiting the Afternoon Constellation requires that Aura's final apogee be at least two kilometers below the minimum perigee of the other constellation members (692 km target)
    - Perform orbit lowering maneuvers centered at apogee and perigee (pairs of maneuvers)
- **Annual updates will be provided**
  - **Final will be produced 60 days before start of decommissioning**
- **Begin work on 2014 Update: ~ Summer 2014**



Flight Dynamics Support Services
FDSS-TO 12-XXXX
CODE 595

Flight Dynamics (FD)
Task Order 12
TECHNICAL MEMORANDUM
Updated Analysis for Aura Decommissioning

Issue Date: September 25, 2012

Prepared by:
Megan Johnson
EOS FDS, Building 32
a.i. solutions, Inc.

Submitted by:
Brian Robinson
FDSS Operations Domain Lead
GSFC FDF, Building 28
a.i. solutions, Inc.

a.i. solutions, Inc.
10001 Derekwood Lane, Suite 215
Lanham, MD 20706

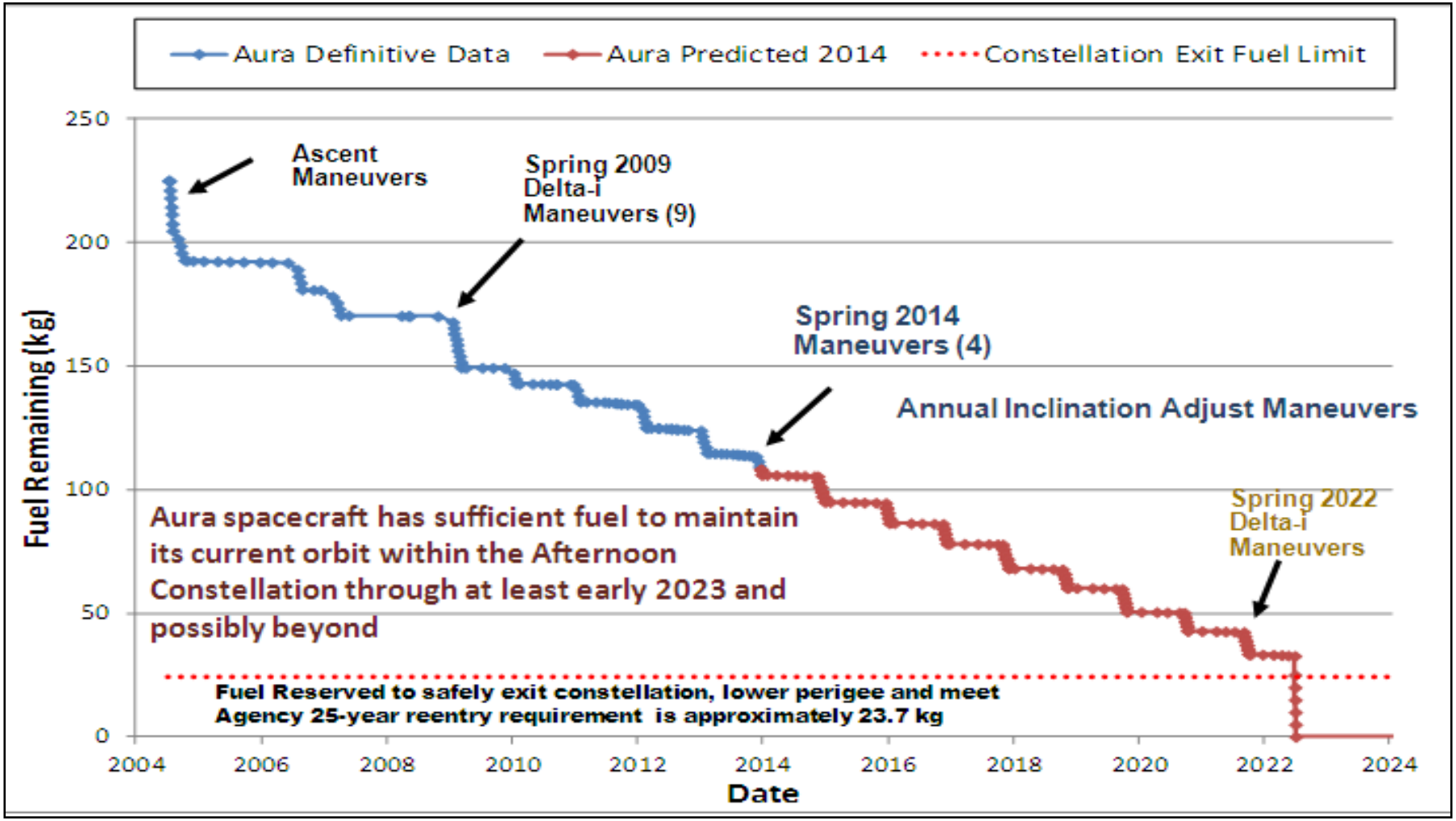
a.i. solutions

Remaining Fuel Estimate

(No changes since September 2013 ESC MOWG @ JPL)

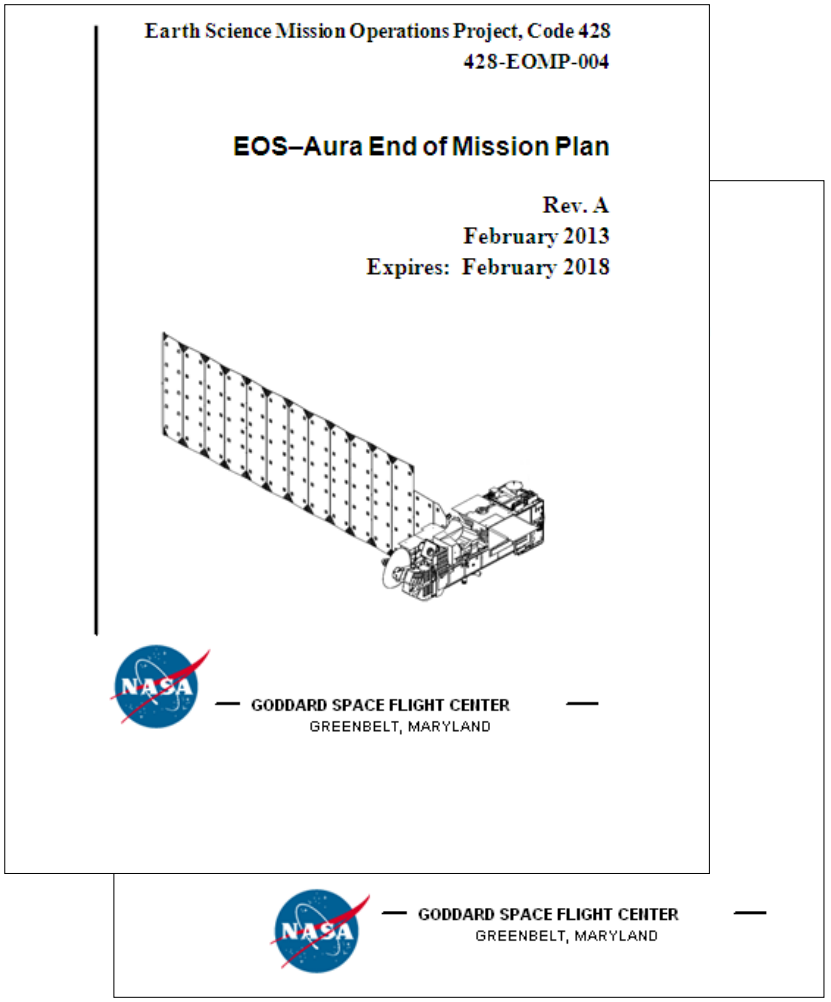
- **Long-term orbit simulations were run for Aura through Feb 2023**
  - **Used mean nominal Schatten solar flux predictions**
  - **Estimated the frequency of drag make-up maneuvers to maintain Aura's WRS-2 ground track requirements**
  - **Estimated the required number of annual inclination maneuvers for Aura to maintain it's mean local time (MLT) requirement**
  - **Did not include potential debris avoidance maneuvers**
  - **Utilized FreeFlyer 6.7.2 which incorporated the solid earth tide model allowing greater accuracy for long term predictions of inclination, beta angle, and mean local time**
- **Lifetime predictions for Aura show that the spacecraft will have sufficient fuel to maintain its current orbit within the Afternoon Constellation through at least early 2023 and possibly beyond**
- **Analyses are updated annually by ESMO Flight Dynamics Team after each series of inclination adjust maneuvers**

Fuel Usage: Actual & Predicted
(Updated April 2, 2014)



Aura End of Mission Plan

- **Initial draft February 2009**
- **Produced the first "Interim" End of Mission Plan (EoMP) in May 2011**
  - **Approved by NASA HQ July 2011**
- **Produced EoMP (Rev A): February 2013**
  - **Updated Lifetime Estimates (09/2012)**
  - **Added Small Object Collision Assessment**
- **Annual updates will be provided until end of mission**
  - **Final will be produced 60 days before EoM**
  - **Latest Annual Lifetime Estimate (09/2013)**
  - **Synopsis**
    - » Exit the A-Train Constellation
    - » Passivate Aqua to the extent possible for uncontrolled reentry
    - » Aqua has **five (5)** waivers for passivation
      - Pressurant Passivation
      - Large Object Collision Probability
      - Small Object Collision Probability
      - Orbital Lifetime
      - Re-entry Risk
- **Begin work on EoMP Rev B: ~ Fall 2014**



Summary

- **Spacecraft Status - GREEN**
- **Instrument Status - GREEN**
  - **HIRDLS: Chopper Stalled 03/17/08 – Not collecting science data**
  - **MLS: Operating Normally – Only periodic Band 13 measurements**
    - » **THz module in Standby Mode – Tested Annually – currently from 08/18/14 - 09/18/14**
    - » **08/06/2013: Band 12 Shut down (reached end of useful life – 2-year design)**
    - » **09/16/2013: 190 GHz Signal Chain Anomaly (Recovered 09/16/2013)**
    - » **08/19/2014: GHz Anomaly (SEU in SAA – recovered the same day)**
  - **OMI: Operating Normally**
    - » **Field-of-View Anomaly started in September 2007 – currently stable**
  - **TES: Operating Normally**
    - » **05/18/2014: TES ICS Stall #2 (Recovered 07/05/2014)**
    - » **07/09/2014: TES Laser A Failure (Switched to Laser B on 7/23/2014)**
      - **TES returned to routine Special Observation operations on 07/26/2014**
- **Data Capture/L0 Processing Status – GREEN**
  - **SSR Data Capture to 08/31/2014: 99.99490238 %**
- **Ground Systems – System Upgrades completed no current issues**
  - **Responding to new security requirements and upgrades to obsolete hardware or COTS systems, as required – Automation Effort underway**

Additional Charts

Maneuvers & Ground Track History
Orbital Trends

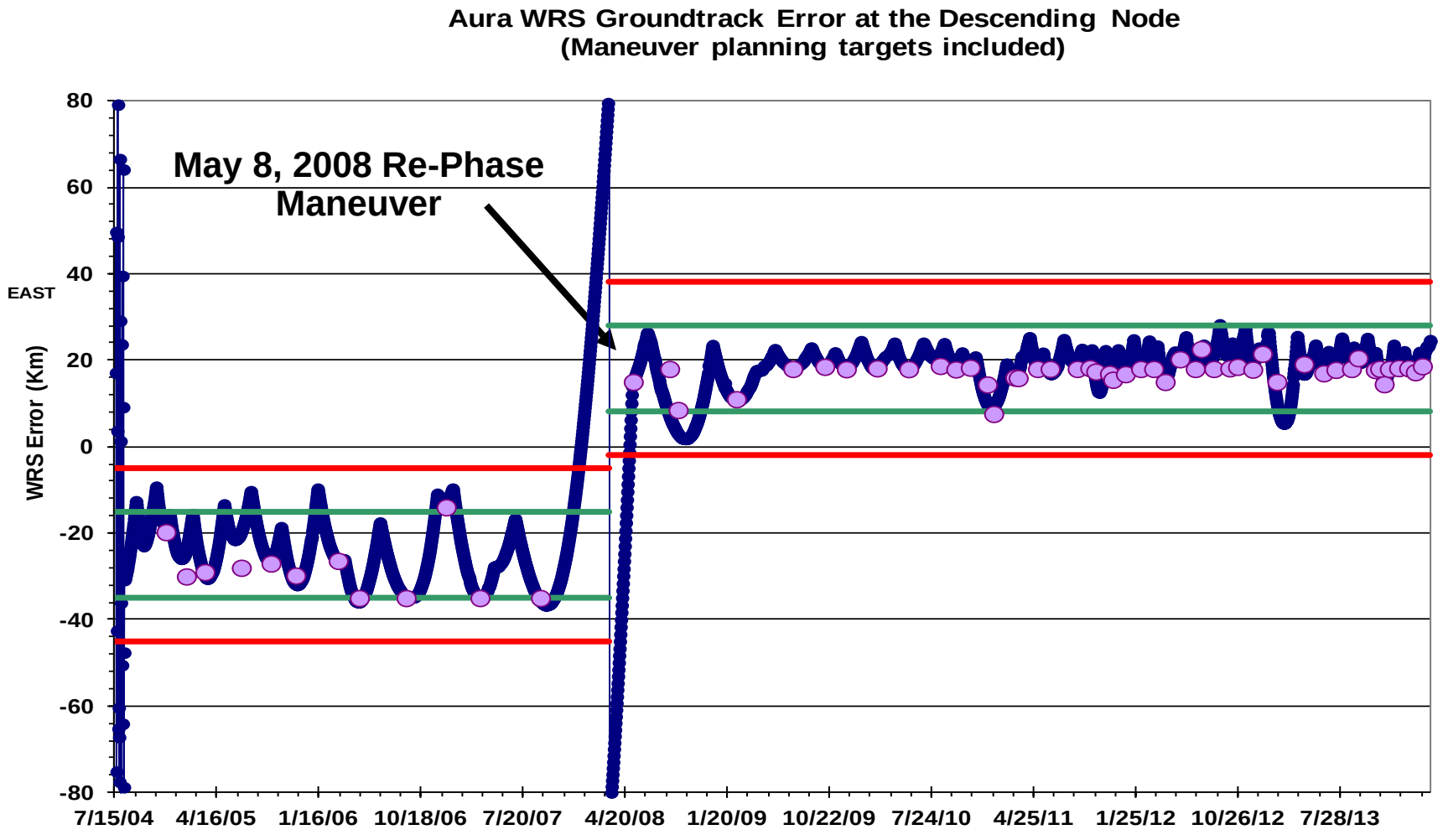
Orbit Maintenance

KEY: Updates since last MOWG in blue

- **Mission Requirements: Perform Drag Make-Up Maneuvers (DMUMs) to maintain Aura's Ground Track Error (GTE) with respect to the World Reference System (WRS-2)**
  - **Requirement: +/-20 Km as measured at the Descending Node**
- **To meet coincident viewing requirements, Aura's initial ground track was offset from Aqua's by one WRS path plus 25.4 Km**
  - **Aura was maintained -5.4 to -45.4 Km west of Aqua until late 2007**
  - **Since May 8, 2008, a new control box, +/- 10 Km from a +18 Km (east) offset of the Aqua WRS-2 path is used to maintain MLS-CALIPSO viewing request**
- **To date a total of 70 routine DMUMs have been performed**
  - **Transitioned to routine no yaw slew DMUMs in 2012**
  - **Last maneuver 08/29/2014 (#70) – Next maneuver 09/24/2014 (#71)**
  - **Variation in performance from –3.5% (cold) to +3.3% (hot)**
- **Conducted 9 series of inclination adjustment maneuvers**
  - **Fall 2004 (4), Fall 2006 (4 of 6), Spring 2007 (4), Spring 2009 (9), Spring 2010 (3),**
  - **Spring 2011 (3), Spring 2012 (4), Spring 2013 (4) & Spring 2014 (4)**
  - **Variation in performance from -1.4 % (cold) to +6.7 % (hot)**

WRS Ground Track Error (GTE)

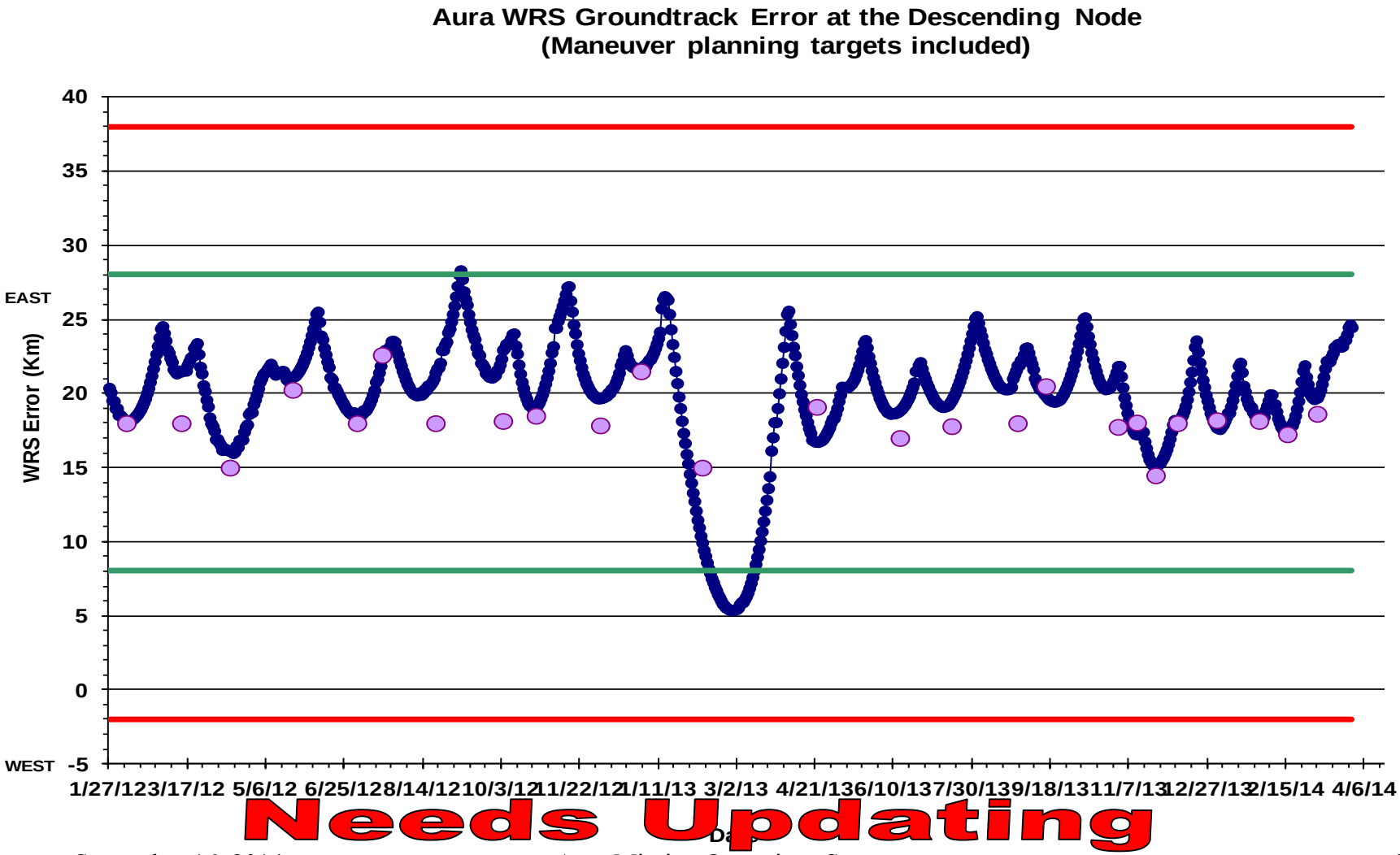
(As of April 2, 2014)



Needs Updating

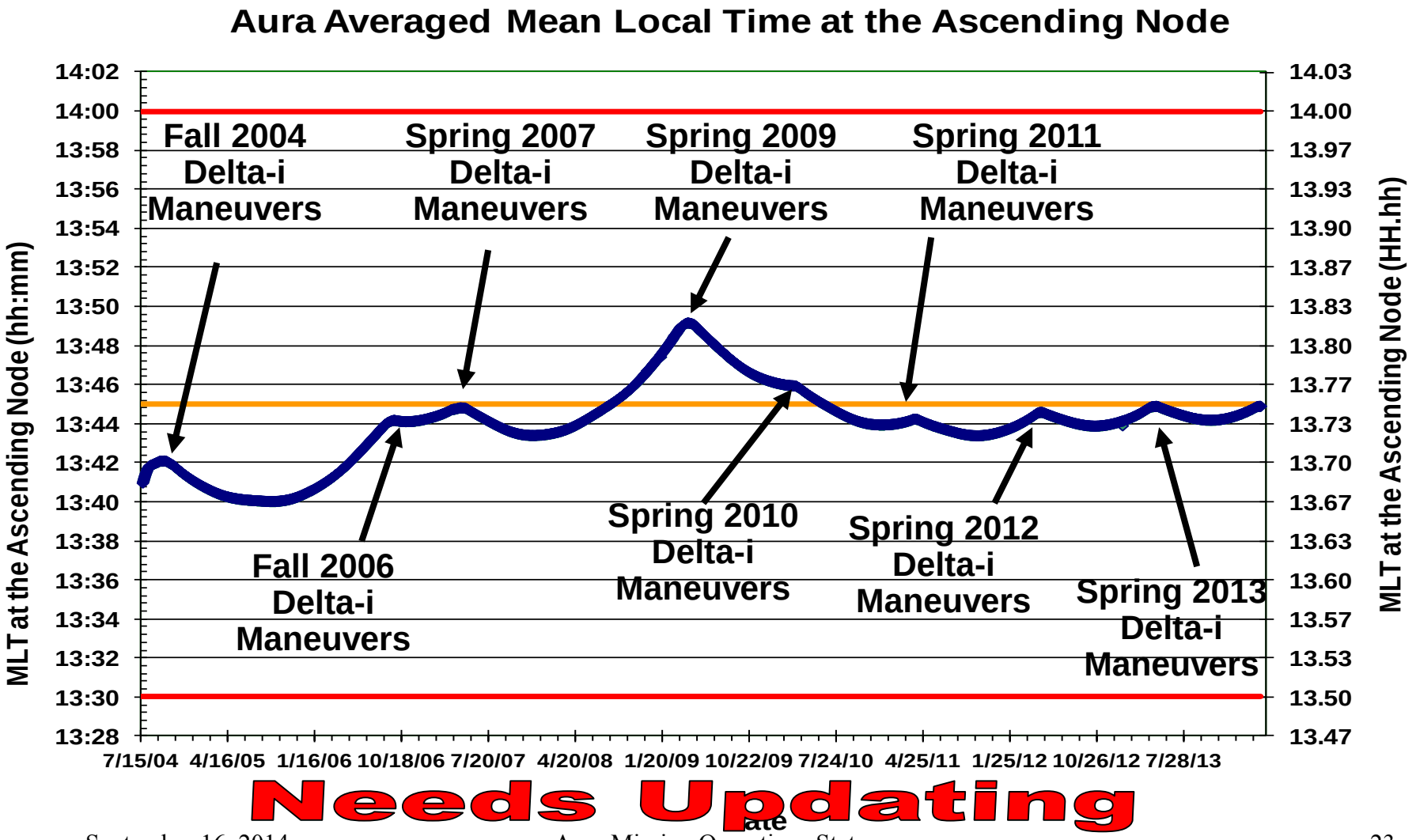
WRS Ground Track Error (GTE)

(As of April 2, 2014 – Past 19+ months)

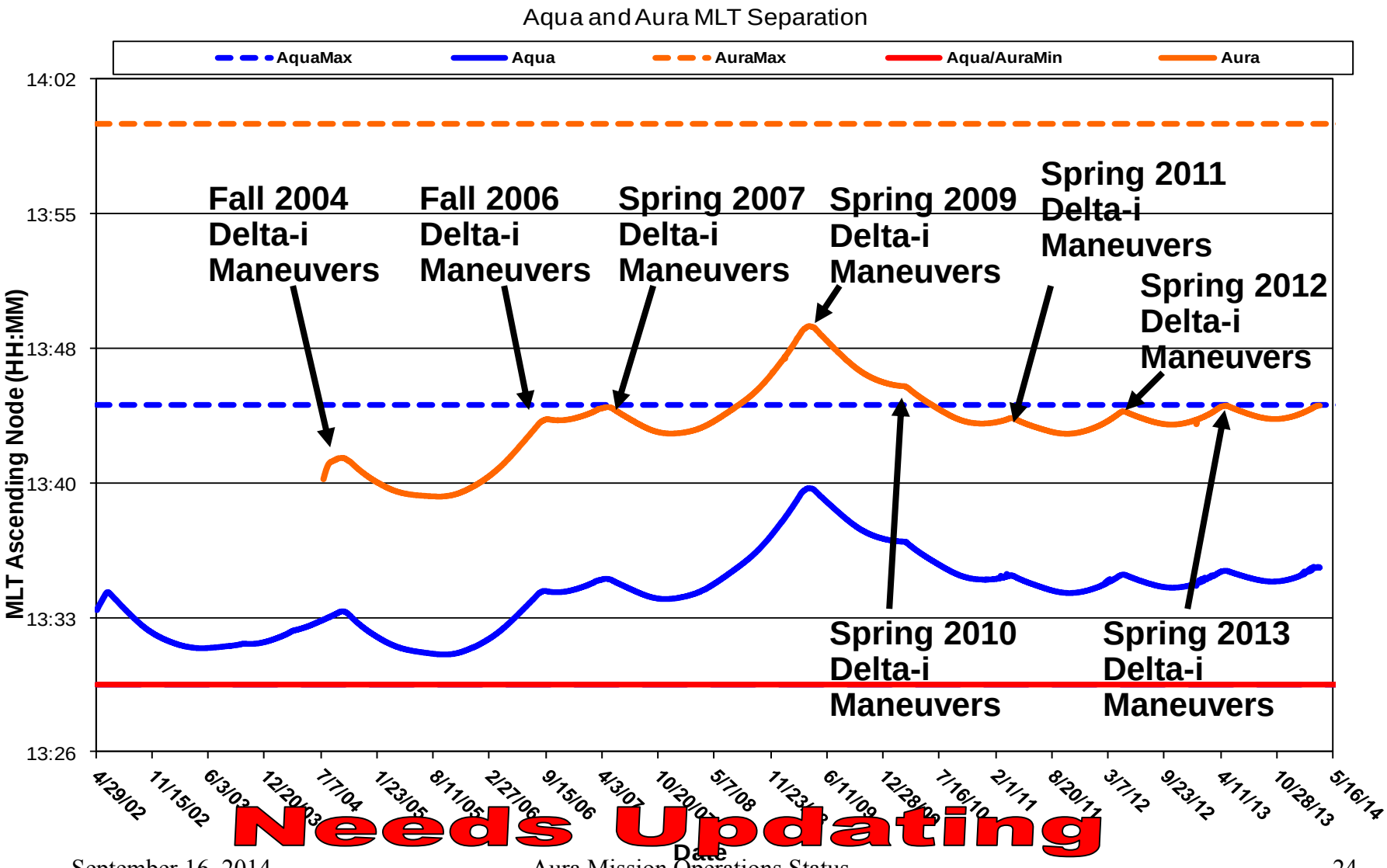


Aura MLT @ Ascending Node

(As of April 2, 2014)



Aqua/Aura Mean Local Time (MLT)
@ Ascending Node



Needs Updating

Aura Predicted Beta Angle
(With Yearly Inclination Maneuvers)

Questions

Backup Charts

Aura Conjunction Assessment High Interest Events

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	3	4	1	8	1	2	0	1	3	4	4	1	32
T3	1	0	0	0	0	0	0	0	0	1	0	0	2
T4	0	0	0	0	0	0	0	0	1	0	0	0	1

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2012	2	4	2	3	3	3	3	1	1	0	1	4	27
T3	0	1	1	0	0	0	0	0	0	0	0	0	2
T4	0	0	0	0	1	0	0	0	1	0	0	0	2

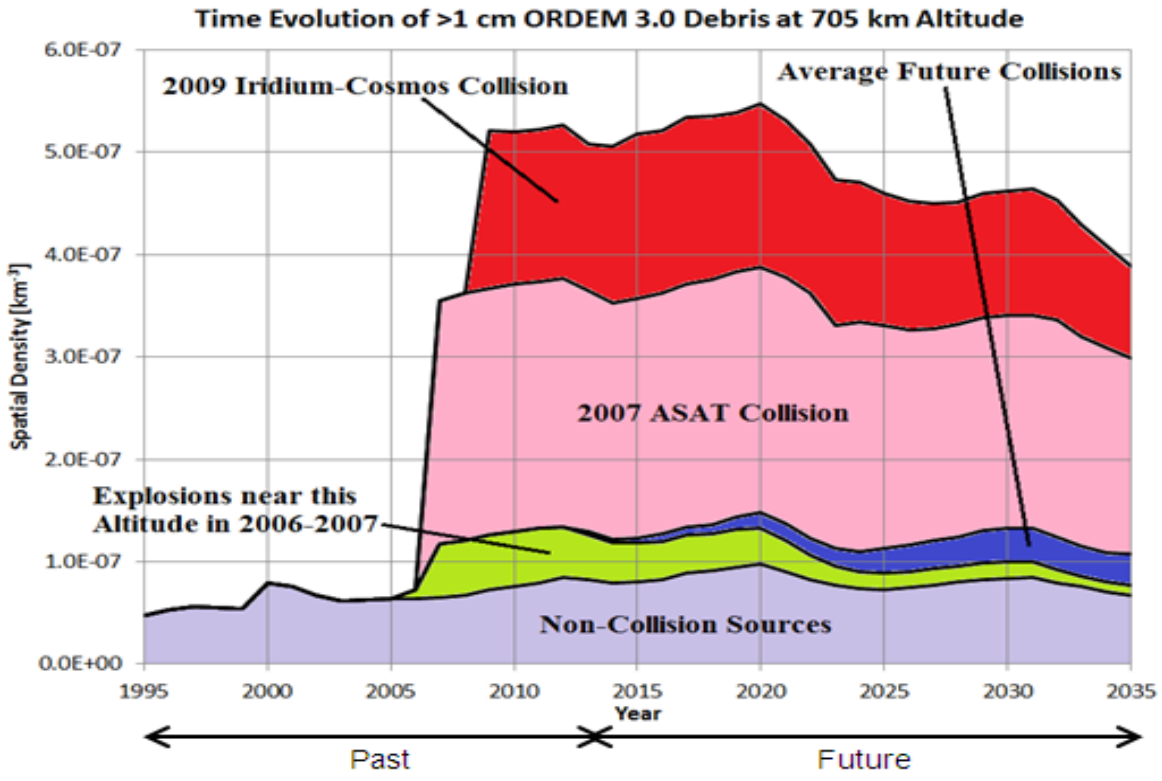
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2013	1	4	3	2	2	1	0	1	3	3	5	4	29
T3	0	0	0	0	1	0	0	1	0	2	2	3	9
T4	0	0	2	0	0	0	0	0	1	0	1	0	4

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2014	1	2	3	3	0	3	2	3					17
T3	0	2	2	1	0	1	0	2					8
T4	0	0	0	0	0	1	0	0					1

Future Debris Population

National Aeronautics and Space Administration

Future Population > 1 cm



Orbital Debris Program Office

Future Space Catalog